# Factors Influencing the Refrigeration of Packages of Peaches

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**Peaches packed in the ventilated basket shown on the cover cooled in less than half the time required for those packed in a standard lined bushel basket.** **See page 455.**

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# Factors Influencing the Refrigeration of Packages of Peaches[a]

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PEACHES of the highest quality in flavor, aroma, and color are produced only when the fruit is allowed to mature on the tree. Such fruit when harvested is only a few days from the ripe stage and the span of life from this stage to overripeness is very short. After harvesting, unless the fruit is to be used immediately, the temperature should be reduced to below 50° F. as quickly as possible. Any delay in cooling may cause heavy losses due to overripeness and decay. The riper the fruit the more necessary it is that it be cooled rapidly.

The losses sustained in transit are at present very large. The average annual loss reported for 1922 to 1928 for officially inspected carloads of peaches, which made up approximately 3 percent of the peaches arriving at the large terminal markets, was $200,000.[2*] Between 5 and 10 percent of the peaches received in New York in 1924 and 1925 reached the market in poor condition and sold at an average discount of 15 percent.[7*] Precooling is generally recognized as a means of greatly reducing such losses.

Many shipping points do not have the facilities with which to precool the fruit before loading it into refrigerator cars. Under such conditions difficulty is experienced in rapidly reducing the temperature of a load of peaches to a point where ripening and decay are effectively retarded. The tests reported in this bulletin were made to determine the factors which influence the rate of cooling of packages of peaches, including the air temperature within the package, the temperature of the fruit at the time of packing, the type of container, and the wrapping of the fruit. The results obtained have a direct bearing on the solution of problems connected with the cooling of fruit within a refrigerator car.

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[a]This is the second report of experiments dealing with factors influencing the refrigeration of packages of fruit. The first, on refrigeration of packages of apples, was published in 1934 as Bulletin 410[3]* of this Station.

*These numbers refer to literature citations on page 464.

## REVIEW OF LITERATURE

Many studies have been conducted in the fields of production, harvesting, and marketing of peaches in an attempt to place a higher quality of product in the hands of the consumer. Because quality is so closely related to time of harvesting, owing to the short span of life of the fruit, a few of the facts established by earlier workers are reported here.

According to Brooks[2*] decay in peaches on the markets is caused principally by brown rot and Rhizopus. The extent of injury due to brown rot is determined more by weather conditions during maturity and harvest than by transit conditions; the extent of injury due to Rhizopus is determined almost entirely by picking, packing, and shipping conditions. Brooks has found that practically the same amount of brown rot will appear on peaches held one day at 75° F. as will appear in three days on fruit held at 50° F.; that Rhizopus rot develops as much in one day on fruit held at 85° F. as in three days on fruit at 59° F., or in ten days on fruit at 50° F., and that at temperatures below 50° F. Rhizopus is seldom able to make a start on stone fruits.

Earlier studies at the Illinois Station[6*] have shown that in refrigerator cars loaded with warm fruit more than two days was required to reduce the temperature of fruit in the top layer of the packages to 50° F.

Test shipments with peaches in crates, reported by Brooks,[2*] showed that in trips lasting 3¼ to 4½ days the temperature in the top layer of the load averaged about 12.5 degrees F. higher than that in the bottom layer. About eight times as long was required for the top layer to reach a temperature of 50° F. as for the bottom layer. Inspection at the marketing points showed 7.8 times as much brown rot and 15.6 times as much Rhizopus rot in the top or fourth layer as in the bottom layer.

Morris[5*] found that a temperature of 32° F. seemed to prevent the normal changes that take place in fruit co-existent with ripening, and that temperatures varying from 40 to 50° F. kept the peaches in good condition and retarded the softening processes, but permitted normal ripening of mature fruit.

Investigations by McMunn and Dorsey[4*] show that with proper handling of peaches, Illinois growers might under certain conditions delay their harvesting operations from five to seven days past the harvesting period now practiced by some growers, and by this delay greatly increase the volume, color, and quality of the fruit.

## EXPERIMENTAL EQUIPMENT AND PROCEDURE

*Apparatus and Procedure.*—The equipment used in the experiments reported in this bulletin and the procedure followed in collecting the data have been described in detail in Bulletin 410, "Factors Influencing the Refrigeration of Packages of Apples."[3*]

The thermocouple arrangements used in the various experiments are shown in Fig. 1. In all packages the thermocouples were arranged in a cross-section thru the center of the package. The thermocouples were inserted so that the point grazed the side of the fruit pit and then passed a short distance into the flesh. In this way the temperature readings were of the flesh in the immediate vicinity of the pit.

*Conditions of the Tests.*—The straight-sided tub bushel basket with ventilated paper liner and corrugated paper facing pad was selected as the standard container for these studies, except where the type of package was under consideration. All tests were made at air velocities below those found to influence the rate of cooling of fruit in a lined tub bushel basket, as reported in Bulletin 410[3*] of this Station.

In order to reduce the number of variables in the experiments, Elberta peaches were used for all tests. The fruit was carefully graded into three sizes: (1) 1¾ to 2 inches in diameter, (2) 2 to 2¼ inches, and (3) more than 2¼ inches. Except as otherwise noted, comparisons were made between fruits of the same size.

## COOLING OF FRUIT WITHIN A PACKAGE

The contents of lined tub bushel baskets packed with Elberta peaches and with Grimes apples cooled in a similar manner when subjected to the same conditions (Fig. 2). The trend of cooling for peaches and apples was determined by packing baskets with fruit at a temperature of about 75° F. and by the use of thermocouples distributed as shown in Fig. 1-E. The baskets were placed in the cooling apparatus, which was maintained at a temperature of approximately 34° F. The data on which Fig. 2 is based represent averages of all the fruit temperatures for apples and peaches respectively at the various reading intervals in a number of tests.

The rate at which the different rows of peaches in a lined tub bushel basket cooled when subjected to a temperature approximately that of air coming from the ice bunker of a refrigerator car (about 34° F.) is shown in Fig. 3. In these tests the thermocouple arrangement shown in Fig. 1-D was used.

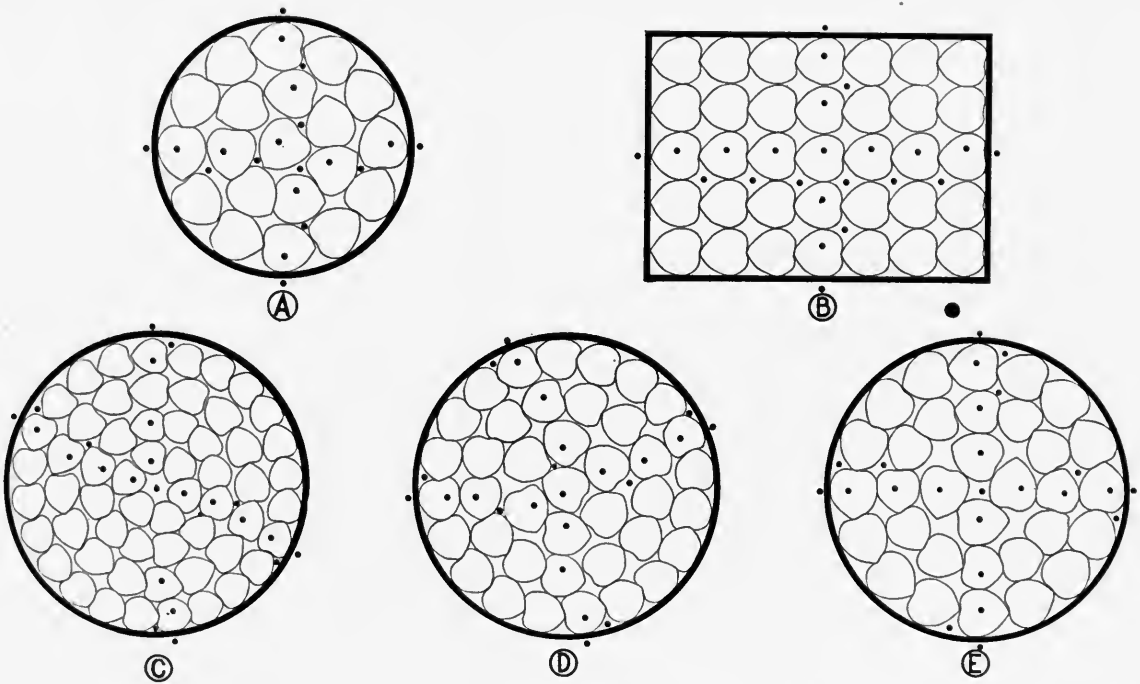


FIG. 1.—CROSS-SECTIONS SHOWING THERMOCOUPLE ARRANGEMENTS USED IN PACKAGES TESTED FOR RATE OF COOLING

(A) Half-bushel basket; (B) corrugated bushel box; (C) lined tub bushel basket packed with peaches less than 2 inches in diameter; (D) lined tub bushel basket and ventilated bushel basket packed with peaches 2 to 2¼ inches in diameter; (E) lined tub bushel basket packed with peaches more than 2¼ inches in diameter.

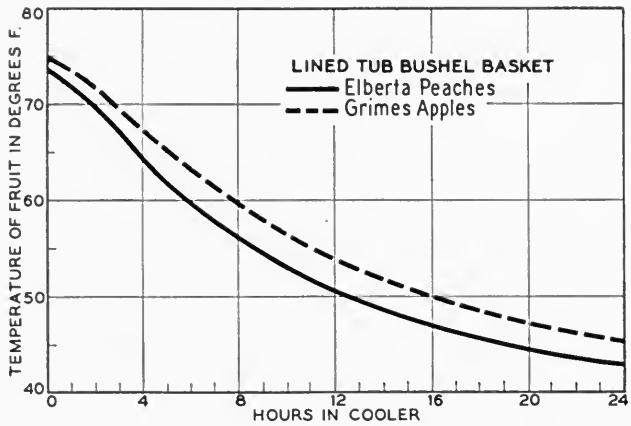


FIG. 2.—PROGRESS OF COOLING OF ELBERTA PEACHES AND GRIMES APPLES PACKED IN LINED TUB BUSHEL BASKETS

In general the progress of cooling was similar for peaches and apples, altho the peaches cooled somewhat more rapidly than the apples during the early part of the cooling period and less rapidly during the latter part.

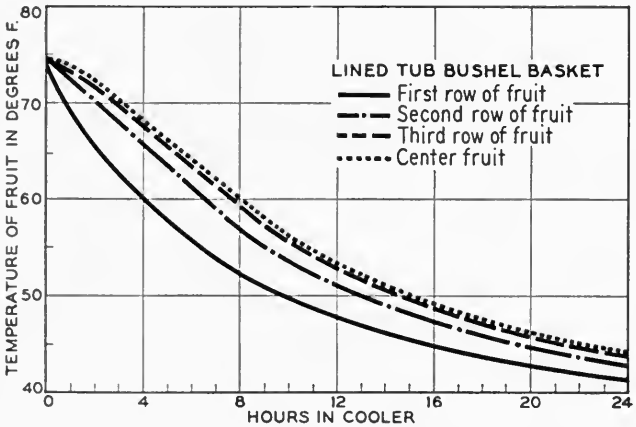


FIG. 3.—PROGRESS OF COOLING OF DIFFERENT ROWS OF FRUIT IN A LINED TUB BUSHEL BASKET OF PEACHES

The temperature difference between the first and second rows of fruit during the early part of the cooling period was considerably greater than the difference between the second and third rows. Likewise the temperature difference between the second and third rows was greater than between the third row and the center fruit.

The first, or outside, row of fruit cooled more rapidly than the second row at the beginning of the test, and likewise the second row cooled more rapidly than the third, and the third row more rapidly than the center fruit. The maximum difference developed between the first and second rows in the early part of the cooling period was 5.5 degrees; between the second and third rows, approximately 2 degrees; and between the third row and the center fruit, considerably less than one degree. As the cooling period progressed, the temperature differences between the rows became less until at the end of twenty-four hours in the cooling chamber the difference between the first and second rows was only 1.5 degrees.

The difference in the rate of cooling between the outside row of fruit and the center fruit is perhaps more fully appreciated when it is noted that the outside row cooled to 50° F. in less than ten hours, whereas fifteen hours was required for the center fruit to cool to this temperature.

The temperature difference between the outside row and the center row of fruit in a basket of Elberta peaches during the cooling period was not so great as that found in a basket of Grimes apples (Table 1).

Analysis of the cooling records of more than 30 peach tests and 40 apple tests indicates that peaches cool more rapidly than apples during the early part of the cooling period. However, as cooling progresses, the rate of cooling gradually changes until the apples cool more rapidly than the peaches. The comparative rates of cooling for the two fruits are most clearly evident when the percentage of cooling is determined for intervals of the cooling period, as shown in Table 2, Part A. In the outside row of peaches 42 to 44 percent of the total temperature reduction for the 24-hour cooling period occurred during the first four hours and in Grimes apples about 40 percent; in the second row of peaches 27 to 29 percent of the reduction occurred during the first four hours and in apples about 19 percent; in the third row of peaches 19 to 22 percent of the reduction occurred in the first four hours and in apples 11 to 13 percent. The same general conditions were found when warm fruit was packed, altho the differences between peaches and apples were somewhat greater with the warm fruit than with fruit lower in temperature (Table 2, Part B).

All rows of peaches within the basket cooled more rapidly during the first four hours than did the apples, but the apples cooled more rapidly than the peaches during the third four-hour period (Fig. 4) and continued to do so until the end of the tests.

TABLE 1.—PROGRESS OF COOLING OF ELBERTA PEACHES AND GRIMES APPLES PACKED IN LINED TUB BUSHEL BASKETS

| Time (hours) | Start | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 12 | 20 | 22 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | (*Temperature in degrees Fahrenheit*) | | | | | | | |
| Air temperature of tunnel | | | | | | | | | | | | | | |
| Peach tests | 35.2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Apple tests | 36.4 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| First row of fruit | | | | | | | | | | | | | | |
| Peaches | 73.6 | 69.8 | 65.9 | 62.7 | 60.0 | 57.6 | 55.6 | 54.0 | 52.4 | 50.1 | 48.0 | 43.0 | 42.2 | 41.3 |
| Apples | 74.9 | 71.5 | 68.2 | 65.2 | 62.4 | 60.0 | 58.2 | 56.5 | 55.3 | 52.7 | 50.5 | 45.2 | 44.3 | 43.6 |
| Second row of fruit | | | | | | | | | | | | | | |
| Peaches | 73.9 | 73.0 | 70.7 | 68.2 | 65.6 | 63.0 | 60.6 | 58.6 | 56.9 | 53.7 | 51.1 | 44.7 | 43.5 | 42.7 |
| Apples | 74.8 | 74.9 | 73.6 | 71.6 | 69.1 | 66.5 | 64.4 | 62.7 | 60.9 | 57.2 | 54.4 | 47.4 | 46.2 | 45.5 |
| Third row of fruit | | | | | | | | | | | | | | |
| Peaches | 73.2 | 73.5 | 72.1 | 70.0 | 67.6 | 65.1 | 62.7 | 60.6 | 58.9 | 55.4 | 52.6 | 45.5 | 44.2 | 43.3 |
| Apples | 74.6 | 75.2 | 74.7 | 72.5 | 71.0 | 68.2 | 66.7 | 64.9 | 62.4 | 59.3 | 56.3 | 50.2 | 47.2 | 46.2 |

TABLE 2.—PERCENTAGE OF COOLING OCCURRING DURING DIFFERENT INTERVALS OF THE COOLING PERIOD IN LINED TUB BUSHEL BASKETS OF PEACHES AND APPLES

| Location of fruit | Elberta peaches | | | | | | Grimes apples | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Packing temperature | Time interval in hours 1-4 | 4-8 | 8-12 | 12-20 | 20-24 | Packing temperature | Time interval in hours 1-4 | 4-8 | 8-12 | 12-20 | 20-24 |
| **Part A—Arranged according to Fig. 1-D** | | | | | | | | | | | | |
| | | *(Percentage temperature reduction)* | | | | | | *(Percentage temperature reduction)* | | | | |
| First row | 74.3° F. | 43.5 | 23.0 | 13.4 | 15.5 | 4.5 | 69.6° F. | 39.5 | 26.6 | 14.0 | 15.4 | 4.5 |
| Second row | 74.6° F. | 29.3 | 26.5 | 18.3 | 20.5 | 5.4 | 71.1° F. | 18.9 | 28.6 | 21.8 | 22.5 | 8.2 |
| Third row | 74.3° F. | 21.8 | 27.4 | 21.1 | 23.4 | 6.3 | 71.0° F. | 10.8 | 26.9 | 24.3 | 28.7 | 9.3 |
| Center fruit | 74.6° F. | 20.2 | 27.2 | 21.5 | 24.2 | 6.9 | 69.8° F. | 9.0 | 23.8 | 23.8 | 30.6 | 12.8 |
| **Part A—Arranged according to Fig. 1-E** | | | | | | | | | | | | |
| First row | 73.6° F. | 42.1 | 23.5 | 13.6 | 15.5 | 5.3 | 74.9° F. | 40.0 | 22.7 | 15.3 | 16.9 | 5.1 |
| Second row | 73.9° F. | 26.6 | 27.9 | 18.6 | 20.5 | 6.4 | 74.8° F. | 19.4 | 28.0 | 22.2 | 23.9 | 6.5 |
| Third row | 73.2° F. | 18.7 | 29.1 | 21.1 | 23.7 | 7.4 | 74.6° F. | 12.6 | 30.3 | 21.5 | 21.5 | 14.1 |
| **Part B—Arranged according to Fig. 1-E** | | | | | | | | | | | | |
| First row | 89.7° F. | 47.5 | 22.2 | 12.1 | 14.1 | 4.1 | 88.3° F. | 38.8 | 23.3 | 18.0 | 15.0 | 4.9 |
| Second row | 89.4° F. | 33.4 | 26.3 | 16.7 | 18.1 | 5.5 | 88.8° F. | 18.7 | 26.9 | 21.8 | 25.9 | 6.7 |
| Third row | 88.1° F. | 26.3 | 27.4 | 18.2 | 20.8 | 7.3 | 88.2° F. | 14.0 | 25.6 | 23.2 | 26.9 | 10.3 |

The difference in the behavior of peaches and apples is an important fact to consider when planning the time necessary to precool refrigerator carloads of these fruits to a satisfactory transit temperature. A suitable transit temperature for peaches is generally recognized as somewhat higher than that for apples.

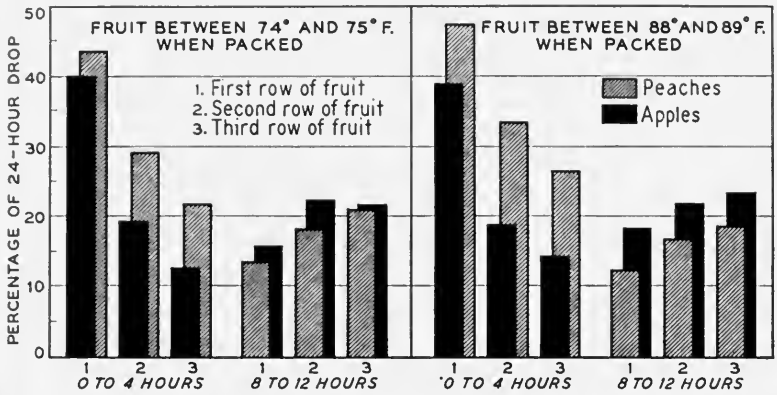


FIG. 4.—COMPARATIVE RATES AT WHICH ELBERTA PEACHES AND GRIMES APPLES COOLED DURING THE FIRST AND THIRD FOUR-HOUR INTERVALS OF THE COOLING PERIOD

The peaches cooled more rapidly than the apples during the early part of the cooling period, but later the apples cooled more rapidly.

### Air Temperatures Within a Lined Tub Bushel Basket

In an effort to secure a better understanding of how fruit in a lined tub bushel basket cools, the air temperatures between the rows of fruit were taken at intervals during the cooling period. The fruit was arranged as indicated in Fig. 1-D. The results shown in Figs. 3 and 5 indicate that the differences in the temperature of the air between the rows of fruit were not so great as the differences in the temperatures of the rows of fruit.

Of greater importance than the mere difference in the temperature range of fruit and air inside the package is the relation of the air temperature to the fruit temperature in the different parts of the package. These relationships are shown graphically in Fig. 6.

The temperature of the air in the spaces between the first and second rows of peaches was about midway between the fruit temperatures of the two rows (Fig. 6-A). The temperature of the air between the second and third rows of peaches was approximately that of the second row of fruit; while the air temperature between

the third row and center fruit was below the fruit temperature of the third row (Fig. 6-B and C). In the tests with apples reported in Bulletin 410[3]* the same relationship between the air and fruit temperatures of the first and second rows of fruit was found as recorded here for peaches. In the apple tests, however, temperature relations of air and fruit in the other rows were not ascertained.

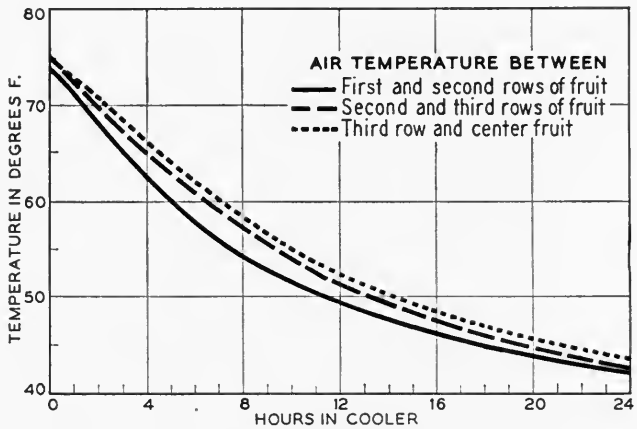


FIG. 5.—AIR TEMPERATURES BETWEEN ROWS OF FRUIT IN A LINED TUB BUSHEL BASKET OF PEACHES

The range in air temperature was not so great as the range in fruit temperature from one row to the next.

In these tests with peaches there was a greater difference between the temperature of the air coming in contact with the second row of fruit from the outside of the row and the temperature of the fruit in that row than there was between the air coming in contact with the third row from the outside of that row and the temperature of the fruit in the row. Likewise the difference between air and fruit temperatures in the third row of fruit was greater than the difference between air and center fruit.

The greater the difference between the air and fruit temperatures, the more rapidly the fruit cooled; and the more nearly the fruit temperature approximated the air temperature in the immediate neighborhood, the more slowly the fruit cooled. These findings help greatly in explaining the wide temperature differences found within a basket of fruit and the influence of the air temperature about the fruit on rate of cooling.

In testing packages to determine the rate at which their contents

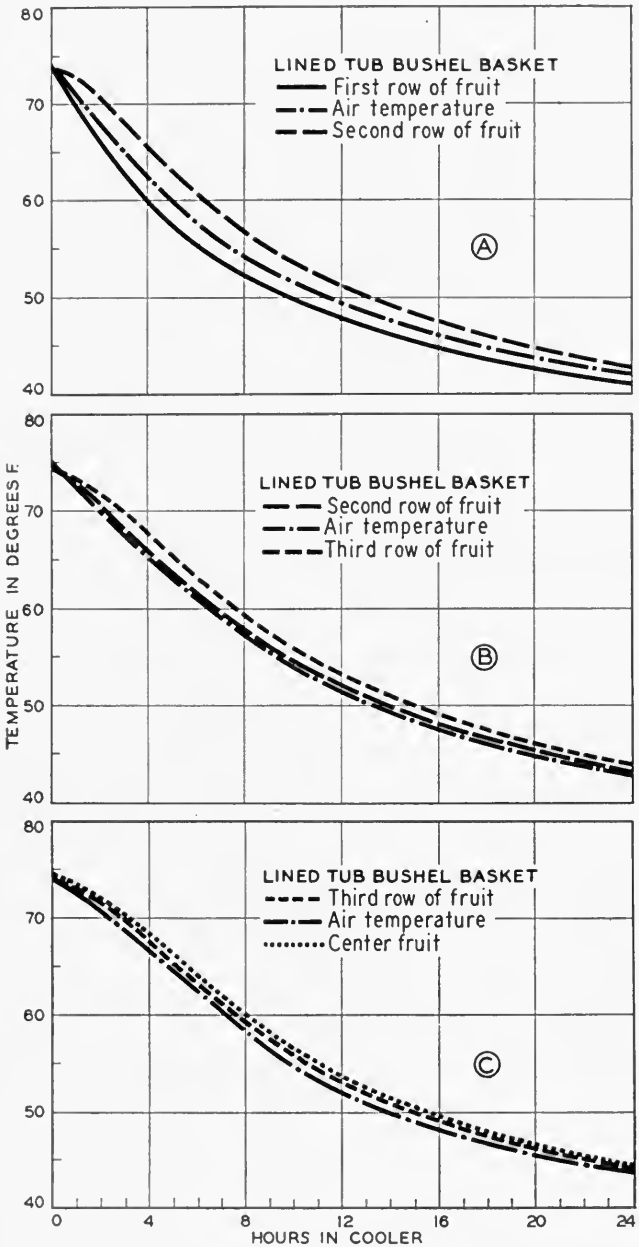


FIG. 6.—AIR AND FRUIT TEMPERATURES IN A LINED TUB BUSHEL BASKET OF PEACHES

cool it was found that in packages permitting rapid cooling, such as the wire-bound slat crate reported in apple tests,[3*] the air temperature between the outer and second rows of fruit was lower than the temperature of the outer row of fruit. The temperature difference between the fruit of the first and second rows in such a container was not so great as that found in corresponding rows in a lined tub bushel basket.

### Size of Fruit Had No Apparent Effect on Rate of Cooling

In order to determine whether size of fruit has any influence on rate of cooling, a number of tests were made with three sizes of Elberta peaches packed in lined tub bushel baskets. The small-size fruits were 1¾ to 2 inches in diameter; the medium, 2 to 2¼ inches in diameter; the large, over 2¼ inches in diameter.

The temperature of the fruit was between 73 and 75° F. when packed. The arrangement of the thermocouples used for the small fruit is shown in Fig. 1-C, for the medium fruit in Fig. 1-D, and for the large fruit in Fig. 1-E.

The rates at which the three sizes of peaches cooled when packed in lined tub bushel baskets are shown in Table 3. These data are averages of all the fruit temperature records for a number of tests with each size of fruit. They support the conclusion reached with respect to the cooling of apples, namely, that size of fruit does not influence the rate at which the contents of a package cool.

## EFFECT OF TEMPERATURE OF FRUIT AT TIME OF PACKING ON RATE OF COOLING

The temperature of the fruit at the time of harvesting determines to some extent the loss that will result from mechanical injury during harvesting and packing and consequent attack by decay organisms, usually brown rot or Rhizopus. Injured fruit is subject to attack as long as the temperature is sufficiently high to allow the decay organisms to become established.

In order to obtain information on the influence of temperature at time of packing on rate of cooling, peaches at three temperatures, approximately 73, 81, and 89° F., were packed in lined tub bushel baskets. These packages were then exposed to a constant cooling temperature of about 36° F. Tho the rate of cooling was more rapid for the fruit packed at the higher temperatures (Fig. 7), a longer time was necessary to reduce it to a safe temperature. About 13 hours was required to reduce the temperature of the 73-degree fruit

TABLE 3.—EFFECT OF SIZE OF FRUIT ON PROGRESS OF COOLING OF PEACHES PACKED IN LINED TUB BUSHEL BASKETS

| Time (hours) | Start | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 12 | 20 | 22 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | (*Temperature in degrees Fahrenheit*) | | | | | | | | |
| Air temperature of tunnel | | | | | | | | | | | | | | |
| Less than 2-inch fruit | 36.5 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| 2- to 2¼-inch fruit | 36.0 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Over 2¼-inch fruit | 36.3 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| First row of fruit | | | | | | | | | | | | | | |
| Less than 2 inches | 74.5 | 69.1 | 65.1 | 61.8 | 58.8 | 56.7 | 54.9 | 53.1 | 51.8 | 49.3 | 47.6 | 42.6 | 42.0 | 41.3 |
| 2 to 2¼ inches | 74.3 | 69.3 | 65.6 | 62.7 | 60.0 | 57.7 | 54.9 | 53.9 | 52.4 | 50.1 | 48.0 | 42.9 | 42.1 | 41.4 |
| Over 2¼ inches | 73.6 | 69.8 | 65.9 | 62.7 | 60.0 | 57.6 | 55.6 | 54.0 | 52.4 | 50.1 | 48.0 | 43.0 | 42.2 | 41.3 |
| Second row of fruit | | | | | | | | | | | | | | |
| Less than 2 inches | 75.1 | 75.1 | 71.1 | 68.5 | 65.5 | 63.0 | 60.6 | 58.5 | 56.7 | 53.3 | 51.0 | 44.4 | 43.4 | 42.5 |
| 2 to 2¼ inches | 74.6 | 72.6 | 70.5 | 67.8 | 65.3 | 63.0 | 60.7 | 58.7 | 56.9 | 53.6 | 51.1 | 44.6 | 43.7 | 42.9 |
| Over 2¼ inches | 73.9 | 73.0 | 70.7 | 68.2 | 65.6 | 63.0 | 60.6 | 58.6 | 56.9 | 53.7 | 51.1 | 44.7 | 43.5 | 42.7 |
| Third row of fruit | | | | | | | | | | | | | | |
| Less than 2 inches | 75.0 | 74.5 | 72.9 | 70.7 | 68.4 | 65.9 | 63.5 | 61.3 | 59.4 | 56.0 | 52.9 | 46.5 | 44.7 | 43.6 |
| 2 to 2¼ inches | 74.3 | 73.4 | 71.9 | 69.7 | 67.7 | 65.3 | 63.2 | 61.2 | 59.4 | 55.8 | 53.0 | 45.9 | 44.8 | 44.0 |
| Over 2¼ inches | 73.2 | 73.5 | 72.1 | 70.0 | 67.6 | 65.1 | 62.7 | 60.6 | 58.9 | 55.4 | 52.6 | 45.5 | 44.2 | 43.3 |
| Fourth row or center fruit | | | | | | | | | | | | | | |
| Less than 2 inches (fourth row) | 75.3 | 74.8 | 73.3 | 71.5 | 69.4 | 66.9 | 64.6 | 62.5 | 60.8 | 57.2 | 54.3 | 46.8 | 45.7 | 44.6 |
| 2 to 2¼ inches (center fruit) | 74.3 | 73.7 | 72.2 | 70.0 | 68.2 | 65.9 | 63.8 | 61.8 | 60.0 | 56.3 | 53.5 | 46.2 | 45.1 | 44.1 |

to 50 degrees, while the 81-degree fruit and the 89-degree fruit required about 16 and 17½ hours respectively to reach an average temperature of 50 degrees.

A more detailed record of how the packages of fruit responded is shown in Table 4. The higher the temperature of the fruit when packed, the wider the range of temperature that developed between the outer and inner rows of fruit during the early part of the cooling

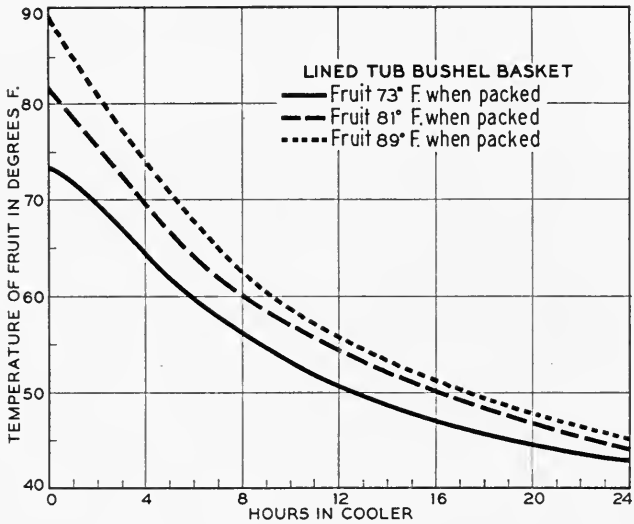


FIG. 7.—RATES AT WHICH THE CONTENTS OF LINED TUB BUSHEL BASKETS OF PEACHES COOLED WHEN PACKED AT DIFFERENT TEMPERATURES

The higher the temperature of the fruit when packed, the more rapidly it cooled, other things being equal. However, at the end of twenty-four hours there was still some difference in the temperature of the contents of the different baskets.

period. At the end of a 24-hour test the temperature differences between the outside and inner rows were between 2 and 3 degrees. At the end of the test there was a difference of 1.7 degrees in the average temperature of the 73- and 81-degree fruit and a difference of 1 degree between the 81- and 89-degree fruit.

Under normal refrigerator car conditions a longer time would be required to reduce the temperature of the fruit to 50° F. than under laboratory conditions, as a uniformly low air temperature is not maintained thruout the refrigerator carload owing to the slow rate at which the cold air comes from the bunkers. The same limiting factor would

TABLE 4.—EFFECT OF TEMPERATURE OF FRUIT WHEN PACKED ON PROGRESS OF COOLING OF PEACHES PACKED IN LINED TUB BUSHEL BASKETS

| Time (hours) | Start | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 12 | 20 | 22 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | (*Temperature in degrees Fahrenheit*) | | | | | | | |
| Air temperature of tunnel | | | | | | | | | | | | | | |
| 73-74° F. fruit | 35.2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| 81-82° F. fruit | 36.1 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| 88-90° F. fruit | 36.2 | .... | .... | .... | .... | .... | .... | .... | .... | .. | .... | .... | .... | .... |
| First row of fruit | | | | | | | | | | | | | | |
| 73-74° F. when packed | 73.6 | 69.8 | 65.9 | 62.7 | 60.0 | 57.6 | 55.6 | 54.0 | 52.4 | 50.1 | 48.0 | 43.0 | 42.2 | 41.3 |
| 81-82° F. when packed | 81.6 | 75.3 | 71.1 | 66.8 | 64.4 | 62.0 | 59.6 | 57.3 | 56.2 | 53.9 | 51.2 | 44.4 | 43.6 | 42.6 |
| 88-90° F. when packed | 89.7 | 81.2 | 76.0 | 71.4 | 67.8 | 64.8 | 62.1 | 59.8 | 57.6 | 54.6 | 52.0 | 45.5 | 44.6 | 43.6 |
| Second row of fruit | | | | | | | | | | | | | | |
| 73-74° F. when packed | 73.9 | 73.0 | 70.7 | 68.2 | 65.6 | 63.0 | 60.6 | 58.6 | 56.9 | 53.7 | 51.1 | 44.7 | 43.5 | 42.7 |
| 81-82° F. when packed | 82.0 | 80.2 | 77.6 | 74.6 | 71.4 | 68.7 | 66.2 | 63.4 | 61.6 | 58.4 | 55.2 | 47.2 | 45.8 | 44.4 |
| 88-90° F. when packed | 89.4 | 86.2 | 82.7 | 78.6 | 74.8 | 71.6 | 68.6 | 65.7 | 63.3 | 59.4 | 56.0 | 48.1 | 46.8 | 45.7 |
| Third row of fruit | | | | | | | | | | | | | | |
| 73-74° F. when packed | 73.2 | 73.5 | 72.1 | 70.0 | 67.6 | 65.1 | 62.7 | 60.6 | 58.9 | 55.4 | 52.6 | 45.5 | 44.2 | 43.3 |
| 81-82° F. when packed | 81.6 | 80.6 | 78.4 | 75.8 | 73.1 | 70.4 | 67.8 | 65.4 | 63.6 | 60.4 | 56.9 | 48.4 | 47.1 | 45.4 |
| 88-90° F. when packed | 88.1 | 86.2 | 83.8 | 80.4 | 77.0 | 73.8 | 70.8 | 68.0 | 65.4 | 61.3 | 57.7 | 48.9 | 47.4 | 45.8 |

probably cause the fruits packed at the higher temperatures to cool proportionately more slowly in the refrigerator car than in the tests here reported.

## EFFECT OF TYPE OF CONTAINER ON THE COOLING OF ITS CONTENTS

Previous tests have demonstrated that the way a car is loaded influences the rate at which the contents cool; and also that the type of container has an effect upon the rate at which its contents will cool when placed in a cooling chamber.


FIG. 8.—TYPES OF PACKAGES USED IN THE TESTS

A—Half-bushel basket; B—ventilated round-bottom bushel basket; C—ventilated tub bushel basket with special liner; D—ventilated corrugated bushel box; E—standard tub bushel basket.

To determine the relative efficiency, from a refrigeration standpoint, of certain packages suitable for the marketing of peaches (Fig. 8), a number of tests were conducted. Since the lined tub bushel basket is the most commonly used container in this region, it was used as the standard with which to compare other containers. The

thermocouple arrangements used are shown in Fig. 1. In so far as possible the arrangement was such as to allow direct comparisons.

### Unlined Tub Bushel Basket

Most growers use a liner in the bushel basket when packing peaches, either in order to use an inverted pack more conveniently or as a protection to the tender fruit. Liners vary in thickness and ventilation facilities. In these tests ventilated liners were used that had twenty-one ¾-inch holes arranged in two rows and located at one-fourth the distance from the top and from the bottom.

Unlined tub bushel baskets packed with peaches cooled a little more rapidly than lined tub bushels, requiring about an hour less time for the average fruit temperature to be reduced to 50° F. (Fig. 9-A). It is questionable, however, whether this increased rate of cooling would justify the omission of a protecting liner when high-quality mature fruit is being marketed. If liners are used, they should be so ventilated as to interfere as little as possible with cooling.

### Ventilated Bushel Basket

Bushel baskets ventilated by means of cracks between the staves have been used by a few growers for marketing peaches. Tests were made with a round-bottom basket having 20 cracks approximately ¾-inch wide at the top and gradually tapering until at the bottom the basket was solid. The cracks allowed a free exchange of air between the inside and outside of the package.

Peaches packed in this ventilated unlined test basket cooled to 50° F. in less than six hours, or in less than half the time (12½ hours) required for the contents of a lined tub bushel basket to cool, tho the average fruit temperature in the ventilated basket at the time of packing was about 2 degrees higher than that of the lined tub bushel basket (Fig. 9-A.)

A study of the temperature drop by two-hour units during the cooling period showed that the ventilated basket cooled much more rapidly during the early part of the cooling period than did the lined tub bushel basket (Table 5). In the outside row of fruit in the ventilated basket 70 percent of the temperature reduction occurred during the first four of the twenty-four hours of cooling and in the lined tub bushel basket 44 percent. In the second row of fruit in the ventilated basket 63 percent of the reduction occurred in the first four hours and in the lined tub bushel basket 28 percent. In the third row of fruit in the ventilated basket 47 percent of the reduction occurred in the

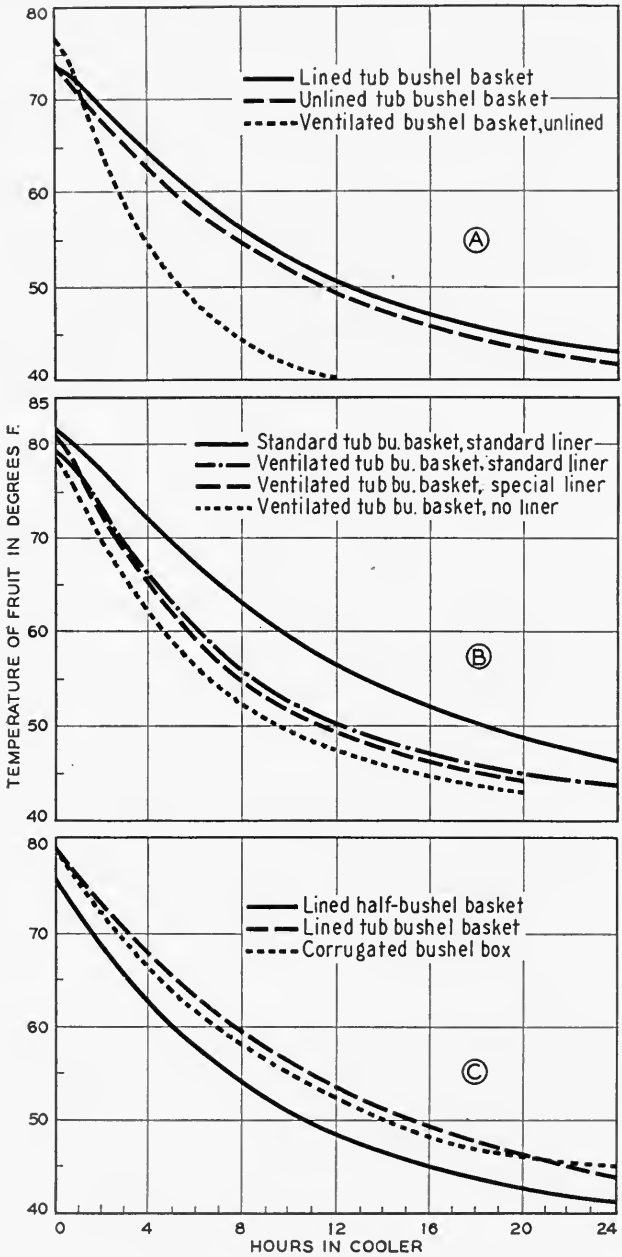


FIG. 9.—PROGRESS OF COOLING OF FRUIT IN DIFFERENT TYPES OF CONTAINERS

first four hours and in the lined basket 23 percent. This very great difference in the rate of cooling shows clearly the importance of the ventilated basket in effecting a rapid cooling of the contents.

In order to obtain more detailed information on the effect of liners on the cooling of the contents of a package, a series of tests was made with a ventilated tub bushel basket of the same shape and dimensions as the standard tub bushel basket commonly used for packing fruit. This basket is used in some places for the packing of vegetables. Ventilation is obtained by so overlapping the staves on the sides of the basket that cracks are formed. The basket used in these tests had 16 cracks averaging 1.25 inches in width at the top of the basket and .4 inch at the base of the basket.

Since peaches were not available when these tests were made, Ben Davis apples were substituted. A lined tub bushel basket, the standard container used for the peach tests, was packed with Ben Davis apples for comparison with the ventilated basket. The thermocouple arrangement used is shown in Fig. 1-E.

Tests of the ventilated tub bushel basket were made using (1) a standard liner, containing twenty-one ¾-inch holes; (2) using a special liner with three ¾-inch holes at each crack of the ventilated basket, the holes being so located that one was at the center of the liner and the others one-fourth the distance from the top and from the bottom; (3) and using no liner.

Apples packed in the ventilated tub bushel basket with a standard liner required only 66 percent as much time to cool as the contents of the lined tub bushel basket, a difference that must be attributed to the structure of the package (Fig. 9-B). The contents of the ventilated tub bushel basket with the special liner cooled in about 60 percent of the time required for the contents of the lined tub bushel basket (Fig. 9-B). When no liner was used, the contents of the ventilated tub bushel basket cooled in about 50 percent of the time required for the lined tub bushel.

The above data show the influence of the structure of the container and of the liner upon the cooling of the contents of the package under a given set of conditions. Rapid cooling can be most satisfactorily obtained by using a package ventilated and lined in such a way as to interfere as little as possible with the exchange of air and yet give the necessary protection to the fruit.

### Lined Tub Half-Bushel Basket

The trend on many markets is toward a smaller package and today many peaches are sent to the market in half-bushel containers. It is

TABLE 5.—TEMPERATURE DROP PER TWO-HOUR INTERVALS IN DIFFERENT ROWS OF WRAPPED AND UNWRAPPED PEACHES PACKED IN LINED TUB BUSHEL BASKETS AND UNWRAPPED PEACHES PACKED IN VENTILATED BUSHEL BASKETS

| Time (hours) | Start | 2 | 4 | 6 | 8 | 10 | 12 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 46 | 48 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air temperature of tunnel | | | | | | | | (*Temperature drop in degrees Fahrenheit*) | | | | | | | | | |
| Lined tubs: fruit unwrapped | 37.8 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Lined tubs: fruit wrapped | 40.0 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Ventilated: fruit unwrapped | 38.3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| First row of fruit | | | | | | | | | | | | | | | | | |
| Lined tubs: fruit unwrapped | 81.6 | 10.5 | 6.7 | 4.8 | 3.4 | 2.3 | 2.7 | .8 | 1.0 | ... | ... | ... | ... | ... | ... | ... | ... |
| Lined tubs: fruit wrapped | 78.6 | 2.3 | 4.1 | 3.6 | 3.2 | 2.8 | 3.0 | 1.6 | 1.0 | 1.0 | .8 | .7 | .6 | .6 | .5 | .2 | 1.0 |
| Ventilated: fruit unwrapped | 76.3 | 18.3 | 9.4 | 4.1 | 2.6 | .9 | .2 | +1.3[1] | 1.2 | ... | ... | ... | ... | ... | ... | ... | ... |
| Second row of fruit | | | | | | | | | | | | | | | | | |
| Lined tubs: fruit unwrapped | 82.0 | 4.4 | 6.2 | 5.2 | 4.6 | 3.2 | 3.2 | 1.4 | 1.4 | ... | ... | ... | ... | ... | ... | ... | ... |
| Lined tubs: fruit wrapped | 78.6 | +1.0[2] | 3.0 | 3.1 | 3.3 | 3.2 | 4.2 | 1.2 | 1.0 | 1.4 | 1.0 | 1.0 | .6 | .9 | .7 | .6 | .8 |
| Ventilated: fruit unwrapped | 76.9 | 15.3 | 11.6 | 5.6 | 4.0 | .7 | 2.3 | +.9[1] | .8 | ... | ... | ... | ... | ... | ... | ... | ... |
| Third row of fruit | | | | | | | | | | | | | | | | | |
| Lined tubs: fruit unwrapped | 81.6 | 3.2 | 5.3 | 5.3 | 4.2 | 3.2 | 3.5 | 1.3 | 1.7 | ... | ... | ... | ... | ... | ... | ... | ... |
| Lined tubs: fruit wrapped | 78.0 | +2.4[2] | 1.5 | 2.5 | 2.2 | 3.0 | 3.0 | 1.5 | 1.3 | 1.6 | 1.6 | .6 | 1.0 | 1.0 | .8 | .8 | .7 |
| Ventilated: fruit unwrapped | 77.0 | 9.1 | 10.8 | 6.8 | 5.2 | 1.3 | 3.5 | +.8[1] | .7 | ... | ... | ... | ... | ... | ... | ... | ... |

[1]The plus sign (+) indicates that the temperature reading showed an increase instead of a decrease compared with the preceding reading. This was undoubtedly due to the "cutting-in" or "cutting-out" of the refrigerating unit shortly before one of the readings was made.

[2]The temperature of the fruit in these baskets was increasing rapidly at the time of packing; the plus sign (+) indicates the rise in temperature near the center of the fruit.

therefore of interest to know how the size of the package influences the cooling of the contents.

Tests were made to determine the rate of cooling of peaches in a lined tub half-bushel basket. The liner was of the ventilated type, having one row of eight ¾-inch holes. The thermocouple arrangement used is shown in Fig. 1-A.

In these tests the peaches in the lined tub half-bushel basket cooled to 50° F. in about 16 percent less time than those in a lined tub bushel basket (Fig. 9-C).

### Ventilated Corrugated Box Showed Same Efficiency as a Lined Tub Bushel Basket

The corrugated package used in these tests was made of single-cell material. The box was of about the same dimensions as a western apple box and was ventilated by seven 1-inch holes in each side and five similar holes in each end. There were no holes in the top or bottom. The thermocouple arrangement used is shown in Fig. 1-B.

Peaches packed in this ventilated corrugated box cooled fully as rapidly as those in a lined tub bushel basket (Fig. 9-C).

Earlier experiments by this Station[6*] showed that carloads of apples packed in corrugated bushel boxes cooled more rapidly than carloads of apples packed in lined tub bushel baskets. Some growers have used corrugated paper cartons in packing apples for a special trade and found them very satisfactory.[1*] There may be conditions that would warrant the use of this package in preference to the tub bushel basket for peaches.

## WRAPPING MATERIALLY RETARDED COOLING

To determine the effect of wrapping peaches upon the rate of cooling, tests were made with lined tub bushel baskets packed with peaches wrapped in 20-percent oil paper wraps. The thermocouple arrangement was the same as for baskets of unwrapped peaches (Fig. 1-E).

The wrapped fruits cooled very slowly. A 34-hour period was required to reduce the average fruit temperature of the wrapped fruit to 50° F., while approximately only 16 hours, or less than half as much time, was required for the unwrapped fruit (Fig. 10).

A study of the temperature drop by two-hour intervals will give a clearer understanding of how the two packages cooled (Table 5). The maximum drop in the outside row of unwrapped fruit during any two-hour interval was 10.5 degrees, whereas the wrapped fruit dropped

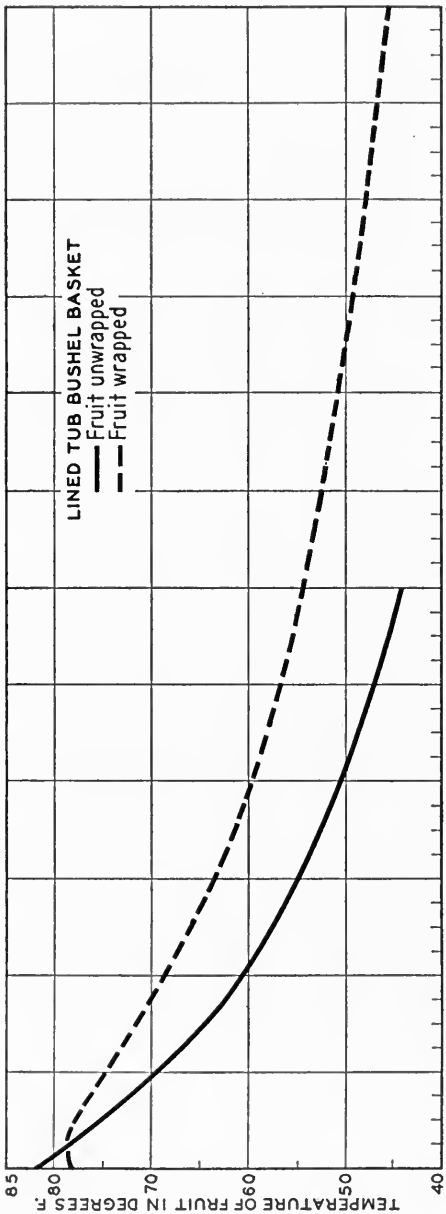


FIG. 10.—PROGRESS OF COOLING OF WRAPPED AND UNWRAPPED PEACHES IN A LINED TUB BUSHEL BASKET
Peaches wrapped in 20-percent oil paper required about twice as long to cool as similar fruit unwrapped.

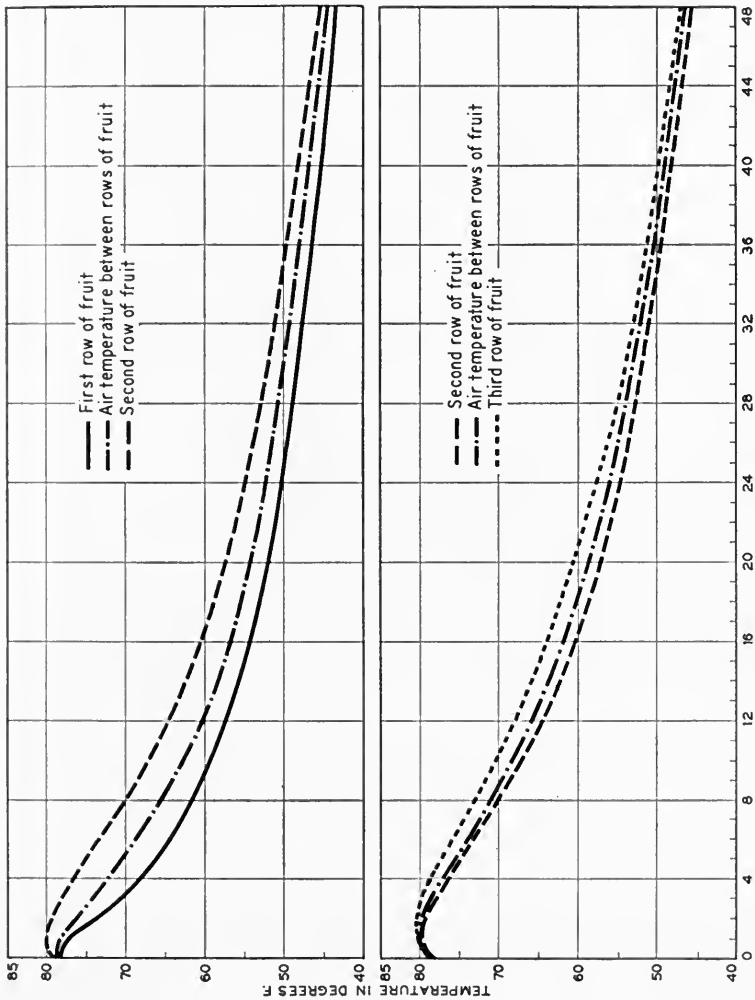


FIG. 11.—AIR AND FRUIT TEMPERATURES IN LINED TUB BUSHEL BASKETS OF WRAPPED PEACHES

The air temperature in the baskets of wrapped fruit more nearly resembled the fruit temperatures than did the air temperature in the baskets of unwrapped fruit.

a maximum of 4.1 degrees in a two-hour interval. The maximum drop in the second row of unwrapped fruit was 6.2 degrees during a two-hour interval, while that of the wrapped fruit was 4.2 degrees. The third row of unwrapped fruit showed a maximum drop of 5.3 degrees and the wrapped fruit 3.0 degrees. For the first 8 hours the outside row of unwrapped fruit cooled more rapidly than the outside row of wrapped fruit, but after that time the wrapped fruit cooled more rapidly. In the second row the unwrapped fruit cooled more rapidly than the wrapped fruit for a period of 10 hours, while in the third row the unwrapped fruit cooled more rapidly than the wrapped fruit for a period of 12 hours.

The relation of air temperature to fruit temperature in a basket of wrapped fruit is shown in Fig. 11. The temperature of the air between the first and second rows of fruit was about midway between the temperatures of the fruit in these two rows (Fig. 9-A), a relationship similar to that found for unwrapped fruit (Fig. 6-A). The temperature of the air between the second and third rows of fruit also registered between the temperatures of the fruit in these rows altho it was closer to the temperature of the second row (Fig. 11) than the third, a relationship between air and fruit temperature that was markedly different from that found in the unwrapped fruit (Fig. 6-B).

The use of wraps is recommended under certain conditions, especially when mature fruit of very high quality is being marketed. As such fruit is very nearly ripe and therefore easily bruised, it is more subject to attack by diseases that cause decay. Wraps tend to protect the fruit against bruising and, especially if chemically treated, against the rapid spread of decay from fruit to fruit.

Investigations have shown that the rate at which the fruit becomes infected and the rate at which the decay develops closely parallel the fruit temperatures[2,5*]. It is therefore important that the fruit be cooled to below 50° F. as quickly as possible. The data presented here show that wraps greatly interfere with cooling. If wraps are to be used, it is advisable to precool the fruit before packing it or at least to harvest the fruit when as cool as possible.

## SUMMARY AND CONCLUSIONS

1. In these tests Elberta peaches packed in lined tub bushel baskets did not develop as great temperature differences between the outside and center rows of fruit as did Grimes apples in similar packages.

2. Under similar conditions, Elberta peaches cooled more rapidly than Grimes apples during the early part of the cooling period, but after six to eight hours in the cooling chamber Grimes apples cooled the more rapidly.

3. In lined tub bushel baskets the air temperature between the outer and second rows of fruit was about midway between the fruit temperatures of the two rows. Progressing toward the center of the basket the air temperature dropped more rapidly than the fruit temperature, so that the air temperature between the third and fourth rows was below the temperature of the fruit in the third row.

4. The rate at which the fruit within a basket cools is largely dependent upon the difference between the temperature of the air about the fruit and the temperature of the fruit. The difference between the air and fruit temperatures is greater for the second row of fruit than for the third row, and the second row cools the more rapidly.

5. The size of peaches used in filling lined tub bushel baskets does not alter the rate at which the contents cool.

6. The higher the temperature of peaches when packed in lined tub bushel baskets the more rapidly they cool when subjected to similar conditions.

7. The use of ventilated liners in well-constructed tub bushel baskets does not greatly interfere with the cooling of the contents.

8. The type of container may influence greatly the rate at which the contents cool. Peaches packed in lined tub bushel baskets and in ventilated corrugated bushel boxes cool at approximately the same rate. The contents of a lined tub half-bushel basket cool more rapidly than those of a lined tub bushel basket. The contents of an unlined ventilated bushel basket cooled to 50° F. in half the time required for a lined tub bushel basket.

9. The use of oil wraps in the packing of peaches materially retards cooling. The difference between the temperature of the outside row of fruit and that at the center of the package is much greater for wrapped than for unwrapped fruit.

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